1994

The alteration to the depot level maintenance strategy of the LPH 2 class: a cost comparison and readiness evaluation

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THE ALTERATION TO THE DEPOT LEVEL MAINTENANCE STRATEGY OF THE LPH 2 CLASS: A COST COMPARISON AND READINESS EVALUATION

by

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Submitted in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
June 1994

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE June 1994	3. REPORT TYPE AND DATES COVERED Master's Thesis

4. TITLE AND SUBTITLE THE ALTERATION TO THE DEPOT LEVEL MAINTENANCE STRATEGY OF THE LPH 2 CLASS: A COST COMPARISON AND READINESS EVALUATION	5. FUNDING NUMBERS
6. AUTHOR(S) Williams, Brian David	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey CA 93943-5000	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.	12b. DISTRIBUTION CODE A

13. ABSTRACT *(maximum 200 words)*

This thesis examines the change in maintenance strategy of the LPH 2 class from the Regular Overhaul strategy to the Phased Maintenance strategy to determine if a cost savings has been achieved. Additionally, readiness was examined through the use of operational availability data and C3/C4 casualty report data to determine the impact of the change in maintenance strategy on readiness. The results of the analysis indicate that with the change in maintenance strategy, a significant cost savings was realized by the Navy. In addition, the research indicated that by both readiness measurements chosen, an improvement in readiness had occurred.

14. SUBJECT TERMS Depot Maintenance, Overhaul, Phased Maintenance, Regular Overhaul, Navy Maintenance, Maintenance Costs	15. NUMBER OF PAGES 82
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)

Prescribed by ANSI Std. 239-18

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

A. BACKGROUND

1. Navy Maintenance

United States Navy ships are among the most sophisticated integrations of complex systems ever assembled on earth. In addition to their complexity, these ships are subjected to the most arduous environmental conditions and the harshest of operational requirements throughout their service life. For these reasons and others, Navy ships require extensive maintenance on a regular basis to sustain battle readiness. Much of the required maintenance is accomplished at the depot level (i.e., in shipyards). Prior to the 1960's, the only Navy depot level maintenance strategy was the Overhaul. Under this plan, a ship entered a public or private shipyard every three to five years, depending on class, and all depot level repairs and preventive maintenance actions requiring shipyard facilities were accomplished. Over the last several decades, the U. S. Navy has developed five principle maintenance strategies for the depot level maintenance of its ships [Ref. 1:Encl. 1:p. 7].

Two of the Navy's depot maintenance strategies, the Regular Overhaul and Phased Maintenance, are the focus of this thesis. As mentioned earlier, the Regular Overhaul was the

only depot level maintenance strategy for the Navy until recent years. Regular Overhauls encompass time periods sometimes in excess of one year.

Phased Maintenance was developed in the early 1970's, partly in response to Congressional inquiry and a General Accounting Office (GAO) report concerning the differences in commercial shipping maintenance and the maintenance of Navy ships of similar configuration. Commercial ships of the time, despite spending far more time underway, spent little time in shipyards and far less money on maintenance than their Navy counterparts[Ref. 2:p. 1-11]. Reasons for the disparity are discussed later. The Navy initially adopted the Phased Maintenance Program for test purposes on one class of auxiliary ships to improve readiness and operational availability of the ships [Ref. 3:p. 4-6]. The program has since grown to include over 150 ships. The Regular Overhaul and Phased Maintenance strategies and other maintenance terms are explained in further detail in Chapter II.

In the early 1980's, the Navy changed the maintenance strategy of the LPH 2 IWO JIMA class Amphibious Assault Ships from the Regular Overhaul to Phased Maintenance for the reasons discussed above.

2. Navy Readiness

Readiness, the ability of a ship to carry out its missions, is a difficult condition to evaluate and much more

difficult to quantify. Numerous attempts have been made to quantify readiness and, more dangerously, attach a dollar figure to it. As this thesis is being written, the United States Congress is debating how much the President's defense budget can be cut without adversely impacting readiness.

With the above in mind, the author has chosen two common measurements of readiness to evaluate the change in maintenance strategy of the LPH 2 class. The first measure chosen is average number of days per year the ship was available for operations(i.e., out of the shipyard). This measure offers a fairly straight forward indicator of one of the primary goals of the Phased Maintenance Program, increased operational availability. The other readiness measure selected is the trends in C3 and C4 Casualty Reports (Casreps).[1] The Casrep information will be evaluated in two ways. First, the trend of all new Initial Casreps[2] will be displayed and evaluated. Then, Casrep data of twelve selected

[1]Casreps - Reports(messages) sent by ships to higher authority detailing an equipment failure, malfunction or deficiency which cannot be corrected within 48 hours. C3 casreps represent a major degradation of a mission area. C4 casreps represent a complete loss of the ability to perform in a mission area. [Ref. 4:Ch. 4:p. 1-5]

[2]Initial Casrep - There are four types of Casreps, Initial Casreps report the initial problem, Update Casreps report progress on the problem, Cascors report correction of the problem and the little used casrep cancellation cancels a casrep. [Ref. 4:Ch. 4:p. 1-5]

Equipment Identification Codes(EICs)[3] will be evaluated. Casrep trend data has been selected to determine if a long term improvement in equipment readiness resulted from the change in maintenance strategy.

It should be noted that these two measurements of readiness are not intended to provide an overall readiness evaluation, rather, as stated, they are simply two of many indicators of ship readiness.

B. PURPOSE

Though the decision to change maintenance strategies was not driven primarily by cost considerations, in today's environment of fiscal restraint all decisions must balance cost concerns with, but not against, readiness.

The purpose of this thesis is to compare and analyze the depot level maintenance costs of the LPH 2 class before and after the Navy changed the maintenance strategy of the class to determine if a cost savings has been realized. Additionally, the cost data will be compared against the two measurements of readiness introduced earlier to determine if an improvement in readiness has occurred.

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[3]EIC - An alphanumeric code used to identify a type or individual piece of equipment. For example: 310C is the EIC for a 60Hz Steam Turbine Driven Generator Set.

C. THE RESEARCH QUESTION

The research questions which will be examined and discussed are as follows:

Did the change in maintenance strategy for the LPH 2 class from a Regular Overhaul to Phased Maintenance result in a cost savings to the Navy?

Did the change in maintenance strategy result in an improvement in ship readiness as measured by trends in C3 and C4 Casualty Reports?

Did the change in maintenance strategy result in an improvement in ship readiness as measured by average days per year the ship was available for operations?

D. SCOPE AND LIMITATIONS

This thesis will only analyze the actual depot level maintenance cost associated with each of the two maintenance strategies employed with the LPH 2 Class. No other costs (i.e., differences in training costs caused by the change in maintenance strategy, etc...) will be considered in the analysis. Depot maintenance cost, schedule, and Casualty Report data for all seven ships in the LPH 2 class for the years 1979 through 1992 will be used. Lack of reliable cost data prevents analysis of years prior to 1979.

The primary limitation on this research was in the casualty report data. In order for this research to remain unclassified, the data on C3 and C4 casreps was collected,

evaluated, and displayed by class vice individual ship. Additionally, no attempt was made to normalize the aggregate data through analysis of individual casreps or groups of casreps.

E. ASSUMPTIONS

The first assumption made in the analysis of the data is that the data is, in fact, an accurate reflection of the actual cost of the depot level maintenance performed.

Second, it is assumed that no cost savings were realized due to a learning curve.[4] This assumption is made for the following reasons; 1) despite the fact that in some cases very similar maintenance projects were accomplished, sufficient differences exist between ships to nullify any possible benefit; 2) depot level work was performed by a number of different shipyards, and; 3) for shipyards performing successive availabilities, sufficient amounts of time lapsed between jobs to negate possible cost savings based on a learning curve.

The third assumption was that the LPH 2 class is a homogeneous class of ships (i.e., there are no significant differences in configuration).

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[4]Learning Curve - Theory forwarding the belief that as a labor action is repeated, the amount of labor hours expended to accomplish the action diminishes. This theory is used extensively with labor intensive production lines. [Ref. 5: p.16-19]

F. DEFINITIONS AND ABBREVIATIONS

Important definitions are explained in the text or are found in footnotes. The list of abbreviations and Navy acronyms for this area of research is too vast to included in this chapter and therefore has been compiled as Appendix A.

G. METHODOLOGY

Introductory data on Navy maintenance policy, past and present, were collected from instructions and notices originated by the Chief of Naval Operations(NAVY STAFF) and through conversations with Naval Sea Systems Command personnel. Cost data for depot level maintenance of the LPH 2 class were obtained from the VAMOSC-SHIPS Management Information System[5], maintained by the Navy Center for Cost Analysis and from the Commander, Naval Sea Systems Command(NAVSEA). Depot maintenance schedule data was received from NAVSEA Detachment PERA (SURFACE)[6]. Casualty report data was obtained from NAVSEA in the form of Annual Casrep Trends Reports and Quarterly Casrep Trends Reports, and from American Management Systems in the form of AD-HOC Data Request.

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[5]VAMOSC - An acronym for Visibility and Management of Operating and Support Costs and is a data base that contains reams of operating cost data for every ship in the Navy.

[6]PERA - An acronym for Planning and Engineering for Repairs and Alterations.

H. ORGANIZATION OF THE THESIS

This thesis is divided into six chapters beginning with this introduction, followed by three appendices.

Chapter II provides some background on the echelons of ship maintenance as well as the different maintenance strategies of the Navy and the various maintenance availabilities associated with these strategies. Additionally, Chapter II gives some background of the LPH 2 class.

Chapter III will identify the costs associated with depot level maintenance of the LPH 2 class using the Regular Overhaul strategy until the mid 1980's and the Phased Maintenance strategy thereafter.

Chapter IV will identify and provide data for the two measurements of readiness to be assessed for the LPH 2 class.

Chapter V contains an analysis of the cost and readiness measurement data collected and an interpretation of the analysis.

The final chapter provides a brief summary of the findings, conclusions and recommendations.

Appendix A provides a listing of commonly used terms and Navy acronyms to assist with the understanding of this thesis.

Appendix B displays the depot maintenance cost data retrieved from the VAMOSC (SHIPS) Management Information System in 1992 dollars.

Appendix C provides the casualty report data received from the Naval Sea Systems Command.

II. NAVY MAINTENANCE OVERVIEW

The purpose of this chapter is to explain the rather complex system used to maintain Navy ships. The chapter will provide some background on maintenance echelons, maintenance strategies and the types of availabilities used with the various strategies. Additionally, this chapter will provide a brief background of the LPH 2 class of ships.

A. MAINTENANCE ECHELONS

In broad terms, Navy ship maintenance is divided into three maintenance echelons. These echelons include 1) organization level maintenance, 2) intermediate level maintenance, and 3) depot level maintenance. [Ref. 6:p. 3]

1. Organization Level Maintenance

Organization level maintenance is the lowest of the maintenance echelons and, as the name implies, is work performed by the organization, in this case the ship's crew. This maintenance is more commonly known as "ship's force" maintenance. Typical ship's force maintenance includes facilities maintenance, routine system and component preventive maintenance and corrective maintenance. Additionally, ship's force personnel document deferred maintenance actions, assist higher level maintenance

activities, and provide quality assurance of work performed by other activities. [Ref. 6:Encl 1:p. 1]

2. Intermediate Level Maintenance

Generally, intermediate level maintenance is work that is beyond the facilities and/or capabilities of the ship's crew but short of the requirements for a shipyard. This level of maintenance is normally carried out while a ship is in an Intermediate Maintenance Availability(IMAV) and is performed by Intermediate Maintenance Activities (IMAs). In the case of ships, the IMAs are either sea based tenders or shore based SIMAs (shore IMAs). It is important to note that in many cases, IMAVs can be carried out while the ship is in port or underway. [Ref. 6:Encl 2:p. 1]

3. Depot Level Maintenance

Depot level maintenance, the highest echelon, is maintenance that requires facilities or capabilities beyond those of the organizational and intermediate levels. This maintenance is performed by both public(Naval) and private shipyards, Naval Repair Facilities (NRFs) and Item Depot Facilities. [Ref. 6:Encl 3:p. 1]

Aspects of Navy depot level maintenance are the focus of this thesis and are explained in further detail below.

B. U. S. NAVY DEPOT LEVEL MAINTENANCE

Depot level maintenance generally involves taking the ship completely out of service or restricting its availability to

the fleet for a period of time. This period of time can range from a few weeks to a few years, depending on many factors. Until the 1960's the Navy's policy was that each ship would enter the "yards" once every three to six years, depending on class, for an Overhaul. The purpose of the Overhaul was to repair everything that was broken, install modernized equipment, and perform preventive maintenance that could only be accomplished in a shipyard. Aside from emergent situations, the ships did not enter the shipyard again until the next scheduled overhaul. Over the years, for cost, operational availability and readiness reasons, the Navy has developed five different depot level maintenance strategies to maintain the large variation of ship types in the fleet. These strategies are explained below.

1. Depot Level Maintenance Strategies

The maintenance strategies currently in use by the Navy include 1) Regular Overhaul, 2) Engineered Operating Cycle, 3) Phased Maintenance, 4) Progressive Maintenance, and, 5) Incremental Maintenance Plan [Ref. 1:Encl. 1:p. 7]. These strategies use a variety of availability types to accomplish maintenance. These maintenance availability types will be introduced and explained later in this chapter.

a. Regular Overhaul

The Regular Overhaul (ROH) was essentially the only maintenance strategy used by the Navy before the 1960's.

This strategy is one in which ships go into the shipyard once every three to six years for depot level maintenance. Only emergency depot level maintenance is performed in the interim. Currently, this strategy is only used with very unique vessels such as floating drydocks.

b. Engineered Operating Cycle

The Engineered Operating Cycle (EOC) was the first new development in the Navy's maintenance policy. The EOC expanded on the concepts of the ROH. In the EOC strategy, scheduled overhauls continue to take place at extended but regular intervals, however, other depot level maintenance is performed in the interim. This additional maintenance takes the form of Selected Restricted Availabilities and Docking Selected Restricted Availabilities which are explained in further detail later.

c. Progressive Maintenance

Progressive Maintenance (PROG) was the first complete departure from the traditional overhaul mindset. In Progressive Maintenance, all overhauls are eliminated and replaced with a maintenance plan that only includes Selected Restricted Availabilities and Docking Selected Restricted Availabilities. This strategy was first introduced on the FFG 7 OLIVER HAZARD PERRY class frigates.

d. *Phased Maintenance*

As stated in Chapter I, Phased Maintenance (PM) was developed in response to Congressional inquiry in the late 1970's. In that time frame, comparisons between maintenance practices for commercially owned ships and those of Navy ships of similar configuration revealed sharp differences in the methods and costs of maintenance. Through the Phased Maintenance strategy, the Navy has adopted several of the common practices of commercial ship maintenance. These practices include:

1. Use of short, repetitive availabilities vice long overhauls(in the civilian world it is unheard of to keep a ship out of use for 6 months or more).

2. Repair only items in need of repair(also known as condition-directed repairs). Traditionally, the Navy maintenance community has used a time-directed repair philosophy in which overhaul and repair of equipment were performed based solely on time elapsed since last repair.[Ref. 3:p. 6]

3. Use of a Port Engineer[7] to assess the actual material condition of the ship and direct all depot level repairs. The Port Engineer acts as the TYCOM[8] representative and works closely with the ship's captain and crew to provide added expertise.[Ref. 3:p. 11]

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[7]Port Engineer - A extremely knowledgeable marine engineer responsible for the managing, planning, execution and evaluation of all depot level maintenance on the ship. [Ref. 3:p. 11]

[8]TYCOM - An acronym for Type Commander who is the administrative superior in a ship's chain of command responsible for maintenance funding.

These changes, along with changes in contract type, supply support and modernization planning, are what distinguish Phased Maintenance from the other maintenance strategies. In a typical five year Phased Maintenance cycle, a Regular Overhaul is replaced by two three-month Phased Maintenance Availabilities and one four-month Docking Phased Maintenance Availability. [Ref. 3:p 6-8]

e. *Incremental Maintenance Plan*

The Incremental Maintenance Plan (IMP) is the most recently developed maintenance strategy to date. This program was developed for the Nimitz class nuclear powered aircraft carriers. The IMP cycle begins with a Nuclear Refueling Complex Overhaul (RCOH) and uses a combination of specialized Phased Incremental Availabilities (PIA) and Docking PIAs (DPIA) to maintain the carriers. [Ref. 1:Encl. 1:p. 3-7] These availabilities are similar to those in the Phased Maintenance Program and therefore, are not explained in further detail in the following section.

2. Types of Depot Level Maintenance Availabilities

There is a near endless list of general to very specialized availability types for depot level maintenance. This section won't attempt to list them all but rather will describe the principle types introduced above.

a. *Overhaul*

Overhauls are major availabilities that usually greatly exceed six months duration and are used for the accomplishment of maintenance and modernization. There are a number of specialized variations of overhaul availabilities such as Regular, Complex and Engineered Overhauls (ROH, COH and EOH). Additionally, there are several specialized overhaul availabilities for the refueling of nuclear powered ships. [Ref. 6:Encl 3:p. 1]

b. *Selected Restricted Availability*

The Selected Restricted Availability (SRA) is a relatively short, manpower intensive industrial period used for the accomplishment of maintenance and selected modernization. A common variation of the SRA is the (DSRA) or Docking Selected Restricted Availability. A DSRA is an expanded SRA which includes maintenance that requires the ship to be drydocked. [Ref. 6:Encl. 3:p. 1]

c. *Phased Maintenance Availability*

The Phased Maintenance Availability (PMA) was specifically developed to properly execute the Phased Maintenance strategy. These availabilities typically last three months and incorporate the advantages developed in the Phased Maintenance strategy. The Docking Phased Maintenance Availability (DPMA) is a variation of the PMA used when maintenance necessitates the drydocking of the ship. [Ref.

6:Encl. 3:p. 2] PMAs and DPMAs contracts are awarded to shipyards utilizing both cost plus type and fixed price contracts. To distinguish between contract types, the commonly accepted terminology is to use PMA/DPMA when referring to cost plus type contracts and PMF/DPMF when referring to fixed price contracts.

d. Depot Modernization Period

The Depot Modernization Period (DMP) is an availability used primarily for the installation of major, high priority warfare improvement alterations [Ref. 6:Encl. 3:p. 1]. These types of availabilities are fairly rare as much of this type work can be scheduled in other availabilities.

C. LPH 2 IWO JIMA CLASS BACKGROUND

1. General Information

The LPH 2 IWO JIMA class amphibious assault ships are the first class of ships specifically designed to operate helicopters. Each ship can carry a Marine battalion landing team, including its vehicles, guns and equipment, plus a squadron of support helicopters [Ref. 7:p. 690]. Table 2-1 on the following page displays additional statistical data on the class and is provided to give some idea of the size and complexity of these ships.

TABLE 2-1. IWO JIMA CLASS GENERAL INFORMATION

Length	602 FT
Beam	104 FT
Draft	32 FT
Displacement(Light)	11250 Tons
Displacement(Loaded)	18300 Tons
Max Speed	23 Knots
Complement	
Officers	47
Enlisted	562
Marine Troops	
Officers	144
Enlisted	1602
Aircraft(Hangar Deck)	
CH 46 Sea Knights	20
OR	
CH 53 Sea Stallions	11
OR	
AV-8B Harriers	12

Source: Jane's Fighting Ship's 1993-94.

2. Ships of the LPH 2 Class

There are seven ships in the LPH 2 class of which LPH 3 and LPH 2 were decommissioned in 1992 and 1993, respectively. LPH 7 is in service but is slated for decommissioning in 1994. Table 2-2 on the following page is provided to identify the ships of the class and shows some pertinent data for the class.

TABLE 2-2. LPH 2 CLASS HULL LISTING

Ship Name	Hull Number	Commissioned	Decommissioned
USS IWO JIMA	LPH 2	26 AUG 1961	14 JUL 1993
USS OKINAWA	LPH 3	14 APR 1962	17 DEC 1992
USS GUADALCANAL	LPH 7	20 JUL 1963	In Service
USS GUAM	LPH 9	16 JAN 1965	In Service
USS TRIPOLI	LPH 10	6 AUG 1966	In Service
USS NEW ORLEANS	LPH 11	16 NOV 1968	In Service
USS INCHON	LPH 12	20 JUN 1970	In Service

Source: Jane's Fighting Ship's 1993-94.

As evident in Table 2-2, the IWO JIMA class is unique in that the hull numbers are not sequential. The reason is that as these ships were being built other ships, primarily older escort aircraft carriers, were being converted to LPHs. Hence, CVE 106 USS BLOCK ISLAND, CVS 21 USS BOXER, CVS 37 USS PRINCETON, CVE 90 THETIS BAY and CVS 45 VALLEY FORGE became LPH 1, LPH 4, LPH 5, LPH 6 and LPH 8, respectively. All of these ships were decommissioned prior to the 1970's. [Ref. 8:p. 465-467] In 1992 and 1993, as mentioned earlier, two ships of the class, LPH 3 and LPH 2, were decommissioned and will be replaced by larger and more capable LHD 1 USS WASP class ships. Eventually all the ships in the IWO JIMA class will be replaced by LHD 1 class ships.

III. LPH 2 CLASS DEPOT LEVEL MAINTENANCE COST DATA

A. OVERVIEW

The period of time chosen for this research is the time frame from January 1, 1979 through December 31, 1992. This period allows for the analysis of a sufficient amount of data under each maintenance strategy.

Although the decision to change the maintenance strategy of the LPH 2 class occurred in February 1984, each ship of the class did not move into the Phased Maintenance Program until the completion of its first scheduled Regular Overhaul following that date. As intended with the implementation of the new maintenance strategy, each ship will be considered to be under the ROH strategy up to and including its last regular overhaul and under the PM strategy thereafter. The 14 year time period chosen will allow for two data points under the ROH strategy for each ship and from one to four data points under the PM strategy for each ship. Figure 1 on the following page illustrates the depot level maintenance availabilities that will be used in the analysis. Additionally, Figure 1 graphically displays the time spans between various types of availabilities.

```
        1979 80 81 82 83 1984 85 86 87 88 89 90 91 1992

     LPH 2  |--------ROH--------------ROH(*)-PMA----DPMA--|

     LPH 3  |-----------ROH-----------------ROH(*)--PMF---|

     LPH 7  |ROH-------------ROH(*)--PMA---PMA---DPMA--PMA|

     LPH 9  |---ROH------------ROH(*)---PMA---DPMA--PMA---|

     LPH 10|-----ROH-------------ROH(*)---PMF--DPMF---PMA|

     LPH 11|------ROH---------------ROH(*)-----PMF--DPMF-|

     LPH 12|-----ROH-------------ROH(*)--PMA-PMA-DPMA-PMA|

     (*) Denotes beginning of Phased Maintenance Strategy
```

Figure 1. LPH 2 Class Depot Maintenance History (1979-1992)

B. DEPOT MAINTENANCE SCHEDULE

Tables 3-1 through 3-7 on the following pages provide a more detailed breakdown of the maintenance availabilities displayed in Figure 1. The tables list the start date, end date, and duration of each depot maintenance availability for each ship that will be used in the cost analysis [Ref. 9:p. 1-4].

TABLE 3-1. LPH 2 DEPOT MAINTENANCE DATA

AVAILABILITY TYPE	START DATE	END DATE	DURATION (DAYS)
ROH	09/22/81	08/23/82	335
ROH	07/02/86	03/02/87	243
PMA	11/07/88	03/07/89	120
DPMA	08/13/91	11/21/91	100
Source: NAVSEA Det. PERA (SURFACE)			

TABLE 3-2. LPH 3 DEPOT MAINTENANCE DATA

AVAILABILITY TYPE	START DATE	END DATE	DURATION (DAYS)
ROH	05/24/82	03/11/83	291
ROH	06/13/88	03/30/89	290
PMF	06/17/91	10/11/91	116
Source: NAVSEA Det. PERA (SURFACE)			

TABLE 3-3. LPH 7 DEPOT MAINTENANCE DATA

AVAILABILITY TYPE	START DATE	END DATE	DURATION (DAYS)
ROH	03/01/79	11/05/79	249
ROH	03/19/84	11/08/84	234
PMA	08/20/86	12/19/86	121
PMA	01/20/88	02/29/88	40
DPMA	03/10/90	08/17/90	160
PMA	10/15/92	01/29/93	106
Source: NAVSEA Det. PERA (SURFACE)			

TABLE 3-4. LPH 9 DEPOT MAINTENANCE DATA

AVAILABILITY TYPE	START DATE	END DATE	DURATION (DAYS)
ROH	03/01/80	09/04/80	249
ROH	09/29/84	07/30/85	304
PMA	06/08/87	10/08/87	122
DPMA	04/03/89	08/04/89	123
PMA	09/26/91	12/20/91	85
Source: NAVSEA Det. PERA (SURFACE)			

TABLE 3-5. LPH 10 DEPOT MAINTENANCE DATA

AVAILABILITY TYPE	START DATE	END DATE	DURATION (DAYS)
ROH	05/23/80	02/22/81	275
ROH	08/05/85	06/06/86	305
PMF	05/23/88	08/26/88	95
DPMF	06/11/90	09/07/90	88
PMA	02/24/92	06/19/92	116
Source: NAVSEA Det. PERA (SURFACE)			

TABLE 3-6. LPH 11 DEPOT MAINTENANCE DATA

AVAILABILITY TYPE	START DATE	END DATE	DURATION (DAYS)
ROH	02/24/81	12/07/81	286
ROH	10/06/86	09/28/87	357
PMF	10/23/89	01/26/90	95
DPMA	11/04/91	05/18/92	196
Source: NAVSEA Det. PERA (SURFACE)			

TABLE 3-7. LPH 12 DEPOT MAINTENANCE DATA

AVAILABILITY TYPE	START DATE	END DATE	DURATION (DAYS)
ROH	08/09/80	06/24/81	319
ROH	04/17/85	11/05/85	202
PMA	10/14/87	02/11/88	120
PMA	09/19/89	12/18/89	90
DPMA	04/01/91	06/25/91	85
PMA	09/29/92	12/02/92	64
Source: NAVSEA Det. PERA (SURFACE)			

C. DEPOT AVAILABILITY COSTS

The cost figures for this research were taken from the VAMOSC-SHIPS Management Information System which is maintained by the Naval Center for Cost Analysis. The system takes operating and support cost inputs from numerous sources and assigns those costs to data elements [Ref. 10:p. 1-6]. The major data elements in the system include:

Element 1.0 Direct Unit Costs

Element 2.0 Direct Intermediate Maintenance

Element 3.0 Direct Depot Maintenance

Element 4.0 Indirect Operating and Support

Each of these elements is subdivided into components which are again subdivided into more precise components to break costs down sufficiently to be useful to the users. All of the

costs which are the focus of this paper are within Element 3.0 Direct Depot Maintenance. Table 3-8 displays the various cost elements used in this research and gives a brief description of the element.

TABLE 3-8. VAMOSC COST ELEMENT DESCRIPTIONS

ELEMENT	DESCRIPTION
3.0	Direct Depot Maintenance
3.1	Scheduled Ship Overhaul
3.1.1	Regular Overhaul (ROH)
3.1.2	SRA, DSRA, PMA, or DPMA
3.2	Non-Scheduled Ship Repair

The actual cost data taken from the VAMOSC Management Information System is displayed in Tables B-2 through B-8 in Appendix B.

IV. READINESS MEASUREMENT DATA

A. OVERVIEW

As stated in Chapter I, two measurements of readiness have been selected to evaluate the change in maintenance strategy of the LPH 2 class. The first measure discussed is the trends in C3 and C4 casualty report data. The second measure is operational availability which is defined, for the purpose of this research, as "out of the shipyards." This definition obviously doesn't, nor is it intended to, take into account other situations in which the ship would be unavailable for operations (i.e., when the ship is in a standdown period, or during work ups, etc..).

B. CASUALTY REPORT DATA

The casualty report data was obtained from the data base maintained by the Commander, Naval Sea Systems Command. Every Casrep generated by every ship in the Navy is entered into this data base. Once entered, the data can be retrieved using a variety of parameters. It should be noted that when a ship enters a depot level maintenance availability, it is removed from the casrep system and all of the ship's casreps are cancelled. This is done because the casrep system was designed to give parts and technical assistance priority to ships in service. When a ship enters a depot level

availability, it is no longer in service and thus doesn't rate the higher priority.

As stated earlier, only initial casreps were used in the analysis. This was done to eliminate the repeat counting of the same casrep item that would occur if update and correction casreps were included. No attempt has been made to qualify or disqualify any of the data for any reason. In other words, the casrep numbers are presented as they appear in the data base. It should be noted that with this data base, as with all data bases, the quality of the output is only as good as the quality of the input and there are many factors that influence the input. Some of those factors include but are not limited to the following:

1) Commanding Officer's Discretion - For a given level of degradation of a piece of equipment one CO may casrep the item while another CO, for any number of reasons, may chose not to casrep the item.

2) Supply Support - Often times a piece of equipment is casreped not because it fits the description of what should be casreped but because a higher priority supply code can be used for parts when the item is casreped.

3) Higher Authority - Occasionally items are casreped as directed by higher authority. In these situations, "higher authority" has identified a reason for all commands holding a

certain piece of equipment to casrep it. The obvious result is a spike in the figures in NAVSEA's data base.

4) Equipment Identification Codes - With thousands of sometimes vague EICs to chose from, differences between what one person will determine to be the "correct" EIC to that of another person are routine.

The first two of these factors are impossible to account for, so, for the purpose of this paper, they are assumed to average out and have no real impact on the data. The third concern represents a fairly rare occurrence and will not be considered in the analysis. The fourth factor is one that has the potential to influence, for better or worse, the casrep totals. To avoid this problem, a selection criteria for the twelve EICs to be analyzed was that these EICs were clearly identified and had little chance of misidentification. A second criteria was that EICs chosen had to be for equipment that was traditionally overhauled in ROH availabilities. The selected EICs are shown in Table 4-1 on the following page.

TABLE 4-1. SELECTED EQUIPMENT IDENTIFICATION CODES

EIC	DESCRIPTION
310C	60HZ Steam Turbine Driven Generator Set
F101	D-Express Header Type Boiler (Main Steam)
YC04	Boat Davits
FB01	Motor Driven Main Circulating Pump
P3*1	AN/SPS 40 Radar Set
5ZEA	MK 115 MOD 0 Guided Missile Fire Control Sys.
T503	Direct Expansion (R-12) Refrigeration Plant
F308	Turbine Driven Main Feed Pump (Centrifugal)
F401	Blower Group (Combustion, Main Propulsion)
TM04	Anchor Windlass
F308	Turbine Driven Main Feed Booster Pump
TU01	Deck Edge Elevators

The Casualty Report data obtained from the Commander, Naval Sea Systems Command is displayed in Tables C-2 through C-5 in Appendix C.

C. OPERATIONAL AVAILABILITY DATA

As stated above, the author's definition of "available for operations" is anytime the ship is not in the shipyard undergoing depot level maintenance. To determine time available for operations, several pieces of information must be known about each ship. The first piece of data necessary is the total time period of the study. As mentioned previously, the time period is January 1, 1979 through

December 31, 1992, a period of 5,114 days. Next, the number of days operating under each of the two maintenance strategies for each ship must be determined. This can be done by determining the first day that each ship entered into the Phased Maintenance Program, then calculate the number of days back to 1/1/79 and forward to 12/31/92. The final information needed is the total number of days each ship spent in the shipyard under each type of maintenance availability. This data was provided in Tables 3-1 through 3-7 in Chapter III. Table 4-2 below provides all the necessary data in tabular format.

TABLE 4-2. OPERATIONAL AVAILABILITY DATA

SHIP	PM STARTING DATE	DAYS IN ROH STRATEGY	DAYS IN ROH AVAIL	DAYS IN PM STRATEGY	DAYS IN PMAs & DPMAs
LPH 2	03/03/87	2,983	578	2,131	220
LPH 3	03/31/89	3,742	581	1,372	267
LPH 7	11/09/84	2,139	483	2,975	427
LPH 9	07/31/85	2,403	549	2,711	330
LPH 10	06/07/86	2,714	580	2,400	299
LPH 11	09/29/87	3,193	643	1,921	291
LPH 12	11/06/85	2,501	521	2,613	359
TOTAL DAYS IN PERIOD FOR ALL SHIPS = 5,114 DAYS					

V. DATA ANALYSIS

A. OVERVIEW

This chapter provides an analysis of the five VAMOSC cost elements chosen for this research. As previously stated, the cost elements are 3.0 Total Depot Level Maintenance, 3.1 Scheduled Ship Overhaul, 3.1.1 Regular Overhaul, 3.1.2 PMAs/DPMAs, and 3.2 Non Scheduled Ship Repair. Following the analysis of the depot level maintenance cost data, the trends in C3/C4 casualty report data are displayed. The final portion of this chapter will be an analysis of the operational availability data.

B. DEPOT MAINTENANCE COST DATA ANALYSIS

Usually, analysis of cost data would first require converting the data to constant dollars. Fortunately, the Naval Center for Cost Analysis was able to provide the data in constant 1992 dollars, calculated using NAVCOMPT inflation indices. This is particularly beneficial because different portions of cost elements are subject to different inflation rates. For example, labor cost would not necessarily be inflated at the same rate as material costs. It would have been difficult to duplicate the accuracy of this method.

The five cost elements chosen for analysis were broken down into three categories. The first category is cost

elements where only an observation of the general trend in cost is desired. These elements include element 3.0, Total Depot Maintenance Costs and element 3.2, Non-Scheduled Ship Repair. This category will be presented first using the aggregate cost figures and then will be normalized using shipyard months.[9] The second category is cost elements in which the data will be manipulated to determine an average cost per day of the two maintenance strategies. The elements include 3.1.1, Cost of Regular Overhaul and element 3.1.2, Cost of PMAs and DPMAs. The third category is element 3.1, the arithmetic sum of elements 3.1.1 and 3.1.2, which serves no purpose other than to show the total amount spent in the depot level availabilities.

The first area of analysis is the 3.0 cost element. As stated earlier, this element covers <u>all</u> depot maintenance costs, including cost incurred under the Fleet Modernization Program(FMP). Because costs of fleet modernization are independent of maintenance strategy, this cost element was not scrutinized, rather, the general spending trend of the element was observed. Figure 2 on the following page displays the trend in the aggregate annual costs for the 3.0 cost element. With the exception of the year 1985, there is a general

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[9]Shipyard Months - Author's term to describe the total number of months spent in the shipyard in a given year for all ships in the class. Calculated using total number of days in availabilities from Tables 3-1 through 3-7 and dividing by 30.

downward trend in the amount of money expended in this cost element. The surge in cost in 1985 was due to the accomplishment of three ROH availabilities is a single year, a rare occurrence for a class of only seven active ships.

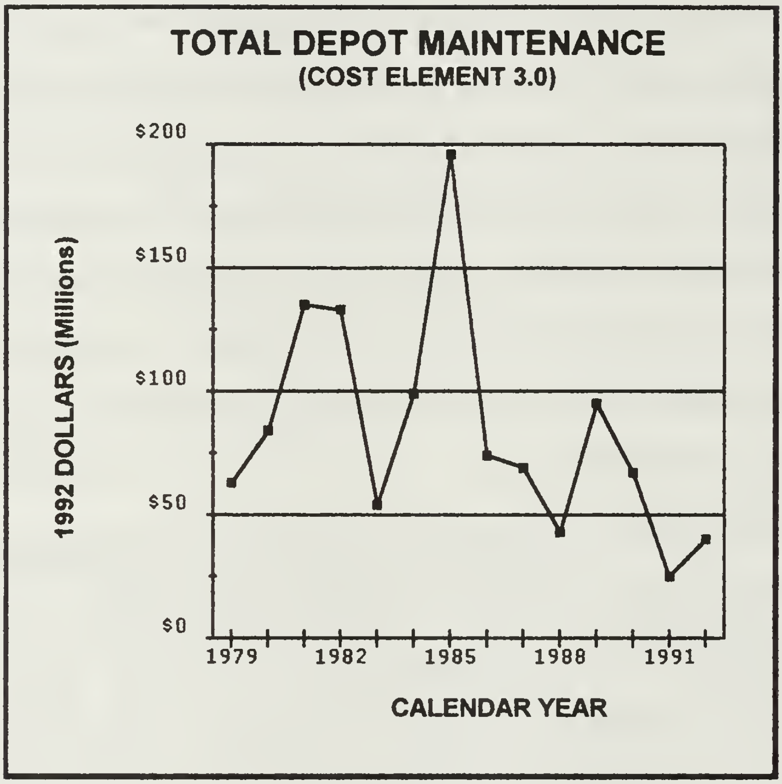

Figure 2. Trends in Cost Element 3.0

The cost data was then normalized using shipyard months. The annual values for shipyard months were calculated using the data in Tables 3-1 through 3-7 and the results are found in Table 5-1 on the following page.

TABLE 5-1. SHIPYARD MONTHS PER YEAR (CLASS TOTAL)

YEAR	SY MONTHS	YEAR	SY MONTHS	YEAR	SY MONTHS
1979	8.3	1984	10.9	1989	17.9
1980	20.4	1985	18.6	1990	9.1
1981	20.5	1986	18.4	1991	14.8
1982	15.2	1987	18.1	1992	13.2
1983	2.3	1988	14.4		

When the data in Figure 2 was normalized using the shipyard months in Table 5-1, the graph was much less erratic. Figure 3 displays the results.

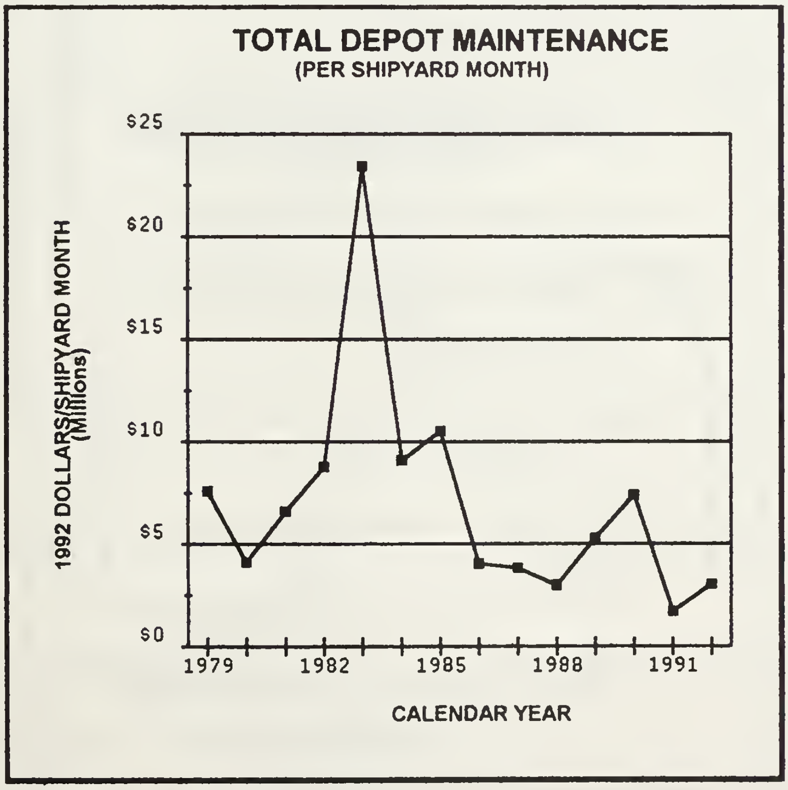

Figure 3. Cost Element 3.0 Per Shipyard Month

Figure 3 also shows a downward trend. Visual inspection reveals that the average cost per shipyard month was in excess of $7.5 million in the early to mid 1980's and below $5 million in the late 1980's and early 1990's. Interestingly, 1983 went from a deep valley in Figure 2 to a tremendous spike in Figure 3. This was due to a relatively small aggregate cost total spread over a very low number of shipyard months(2.3).

The next area of analysis is the 3.2 cost element. This element, covering non scheduled ship repair, was also observed solely for general trends in costs. As with the 3.0 element, the general trend was clearly downward. Figure 4 below displays the trend graphically.

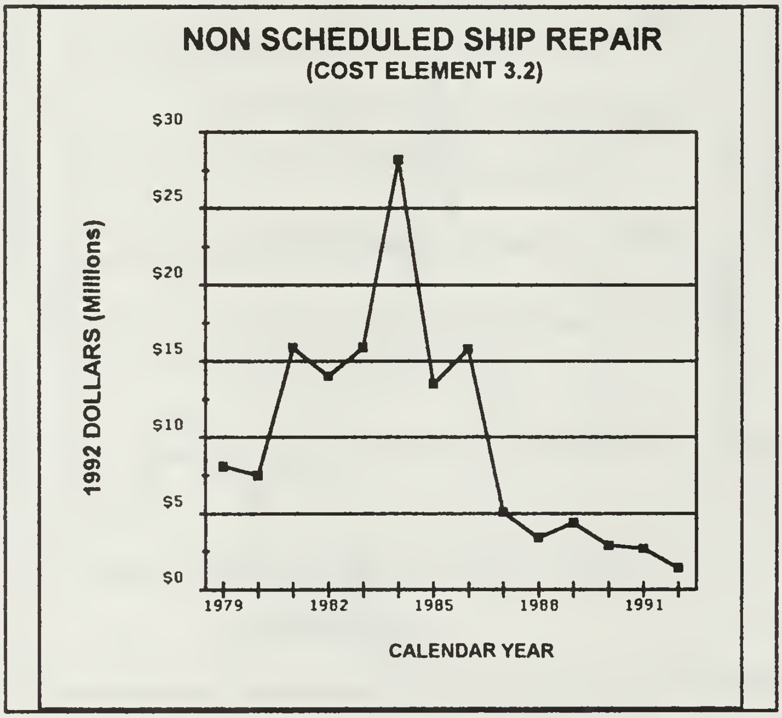

Figure 4. Trends in Cost Element 3.2

As with the 3.0 cost element, cost element 3.2 was then normalized using the same values for shipyard months. The results are displayed in Figure 5. Again with the exception of 1983, there is a clear downward trend. The severe anomaly in 1983 would lead one to believe that there may exist an error in the data.

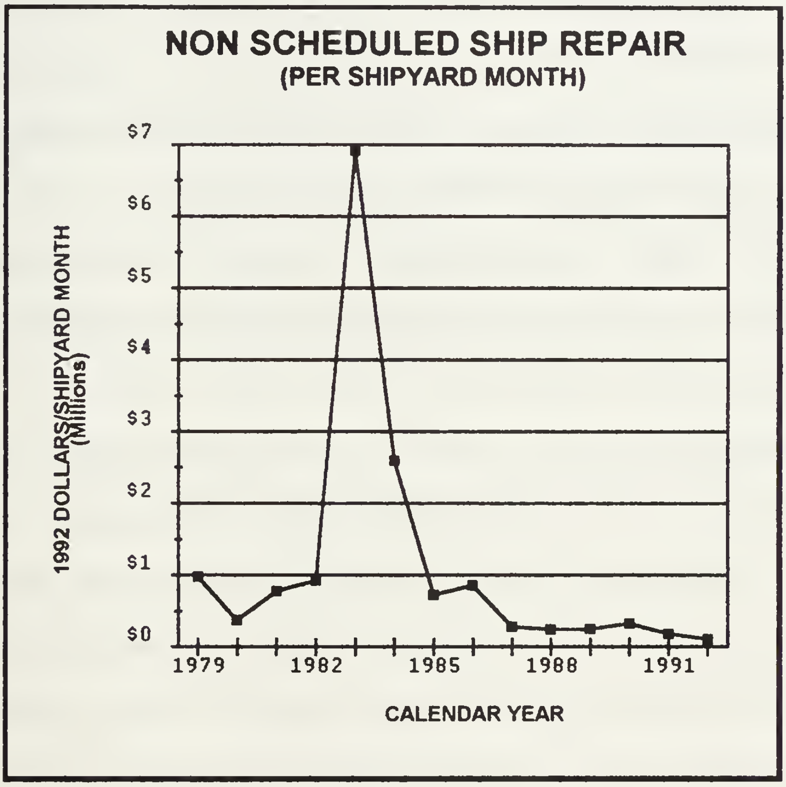

Figure 5. Cost Element 3.2 Per Shipyard Month

The next area of analysis is with cost elements 3.1.1 and 3.1.2, cost of Regular Overhauls and cost of PMAs/DPMAs respectively. Costs in the 3.1.1 cost element are associated with the ROH strategy while cost in the 3.1.2 cost element are

associated with the PM strategy. To compare the costs of these elements to one another, a value for average cost per day that a ship was under each of the two maintenance strategies will be determined. The elements will be analyzed together but will use different denominators to calculate the values for average cost per day. The denominator for analysis of the 3.1.1 cost element will be the total number of days in one complete ROH cycle.[10] From Figure 1, it can be seen that each of the ships in the class had two ROH availabilities during the time period chosen for analysis. The ROH cycle used for each ship will be from the day following the first ROH availability listed through the last day of the second ROH availability.

The denominator for the 3.1.2 cost element will be the total number of days that each ship was under the Phased Maintenance strategy during the selected period of analysis. That time period for each ship is from the day following the last ROH availability through December 31, 1992. The reasoning behind the different denominators is that with the ROH strategy, there are time periods where there are concentrations of very high costs followed by periods with no costs. Using the time period from January 1, 1979 through the last ROH availability(the period in which the ship was under

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[10]ROH Cycle - The period from the first day following an ROH availability through the last day of the subsequent ROH availability.

the ROH strategy) instead of a ROH cycle would cause the average cost to be much higher for a ship with two ROH availabilities in a span of five years than for a ship with two ROH availabilities in the span of nine years. For example, contrast LPH 3 and LPH 7 in Figure 1. With the PM strategy, availabilities occur fairly frequently and spreading the aggregate costs over the entire time period is more appropriate.

As can be seen by looking at the data in Appendix B and comparing it to the tables listing the dates of the maintenance availabilities in Chapter III, not all cost appear to readily match an availability. This is caused primarily by the large time span over which bills are received and paid. This impacts the results in two ways. First, not all of the cost of an availability are captured in the year(s) the availability took place. Some costs are incurred before the availability start date and some costs are not realized until after the completion of the availability. For this reason, the cost of the last ROH availability will include the 3.1.1 costs for a period beginning one year before the ROH start date through a point two years after the completion date. This method will account for the bulk of the costs of the availability. Second, because not all cost are recognized in the year the availability took place, the costs of some of the PMAs/DPMAs may be understated since cost data may still be accumulating for availabilities that took place in 1991/92.

The following is an example of the calculations. For LPH 11 USS NEW ORLEANS, the last ROH availability occurred in 1986-87, from Table B-7 the total cost under the 3.1.1 cost element for 1985-89 was $16,605,171; from Table 3-6, the ROH cycle was 2,119 days, yielding an average cost per day of $7,836. For the PM strategy, the aggregate cost of the 3.1.2 cost element was $17,574,361; from Table 4-2, the USS NEW ORLEANS spent 2,400 days under the PM strategy, yielding an average cost per day of $9,149. Note that these figures represent the average cost per day that the ship was under the different maintenance strategies not the average cost per day that the ship was in depot level availabilities. Table 5-2 on the following page provides the results of the calculations for the remainder of the class as well as an average for the class for both strategies. Figure 6 on the following page displays the same information graphically.

TABLE 5-2. MAINTENANCE STRATEGIES: AVG COST/DAY

	AVERAGE COST PER DAY	
	ROH STRATEGY	**PM STRATEGY**
LPH 2	$ 8,370	$ 5,242
LPH 3	$ 35,410	$ 4,669
LPH 7	$ 18,441	$ 5,398
LPH 9	$ 20,498	$ 5,924
LPH 10	$ 7,801	$ 7,695
LPH 11	$ 7,836	$ 9,149
LPH 12	$ 18,134	$ 5,558
AVERAGE	$ 16,641	$ 6,234

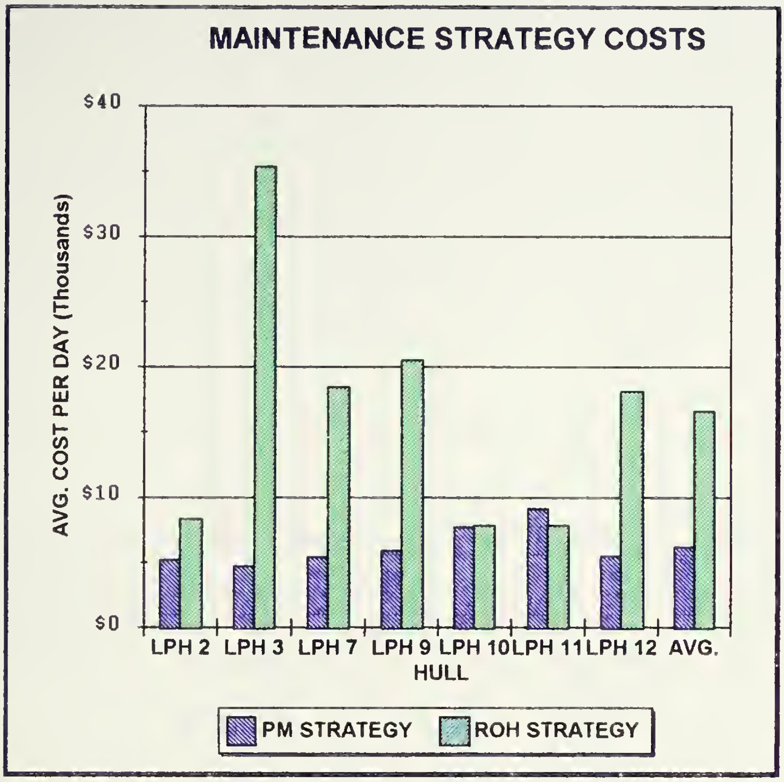

Figure 6. Maintenance Strategies: Avg Cost/Day

C. READINESS MEASUREMENT DATA ANALYSIS

1. Casualty Report Data

Analysis of the casrep data is the least scientific portion of this chapter. For purposes of evaluating readiness, it is impossible to attribute individual casreps to one maintenance strategy or the other, so the overall trend in casreps through the years is what is desired. As stated in Chapter I, the casrep data was provided for the entire LPH 2 class vice individual ship in order to keep the research unclassified. However, because ships in depot level

availabilities are not in the casrep system, the aggregate casrep totals must be normalized to account for this difference. The method chosen to normalize the data is by available month.[11] By subtracting each of the numbers in Table 5-1 from the total month figure of 84, the available months for each year can be calculated. The results are shown in Table 5-3.

TABLE 5-3. AVAILABLE MONTHS (CLASS TOTAL)

YEAR	AV MONTHS	YEAR	AV MONTHS	YEAR	AV MONTHS
1979	75.7	**1984**	73.1	**1989**	66.1
1980	63.6	**1985**	65.4	**1990**	74.9
1981	63.5	**1986**	65.6	**1991**	69.2
1982	68.8	**1987**	65.9	**1992**	70.8
1983	81.7	**1988**	69.6		

Using the data in Table 5-3 to normalize the casrep data found in Appendix C, the graph in Figure 7 was constructed. Figure 7 displays the data broken down into C3

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[11]Available Months - Author's term used to describe the total number of months out of depot maintenance for a given year and is essentially any month that is not a "shipyard month." For any given year there are 84 total months (12 months X 7 ships) so,

Shipyard Months + Available Months = 84

casreps, C4 casreps, and total C3/C4 casreps. For comparison purposes, the aggregate casrep totals are displayed on the following page in Figure 8. In both cases, the graphs show two clear spikes with apexes in the years 1981 and 1989. Further investigation of the data didn't reveal any clear reason or pattern for either of the spikes. In both cases, the increase in casreps was spread over a wide range of equipment identification codes.

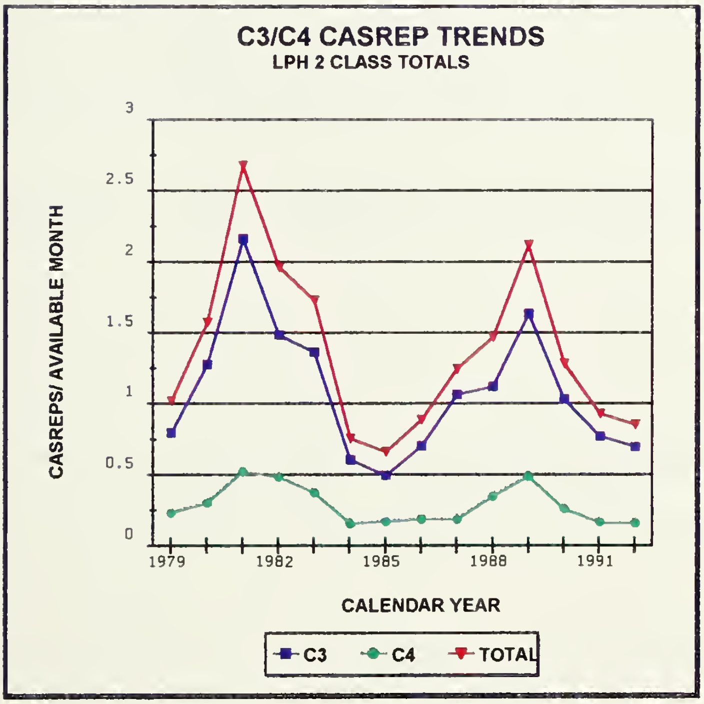

Figure 7. Casreps Per Available Month

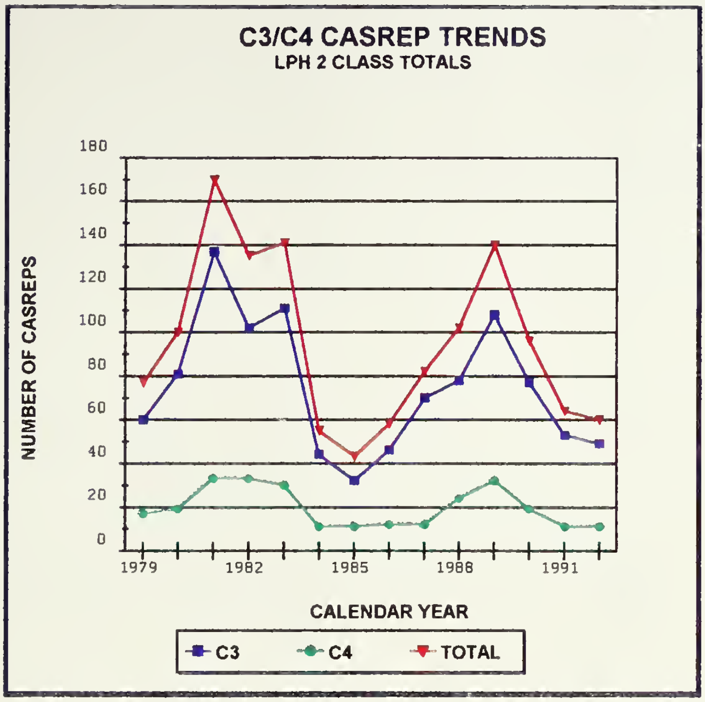

Figure 8. Class Totals for C3/C4 Casreps

The next area of analysis is with the C3/C4 casreps of the 12 selected EICs. The data from Appendix C has been normalized and displayed graphically in Figures 9 through 12 on the following pages. With these figures only the total of C3/C4 casreps for each EIC are displayed. The data reveals that in most cases the trend in C3/C4 casreps improved (less casreps) or at worst stayed about the same. Two EICs, 310C and P3*1 appeared to follow the spikes that appeared in the graphs for total casreps, while EIC 5ZEA actually seemed to get worse.

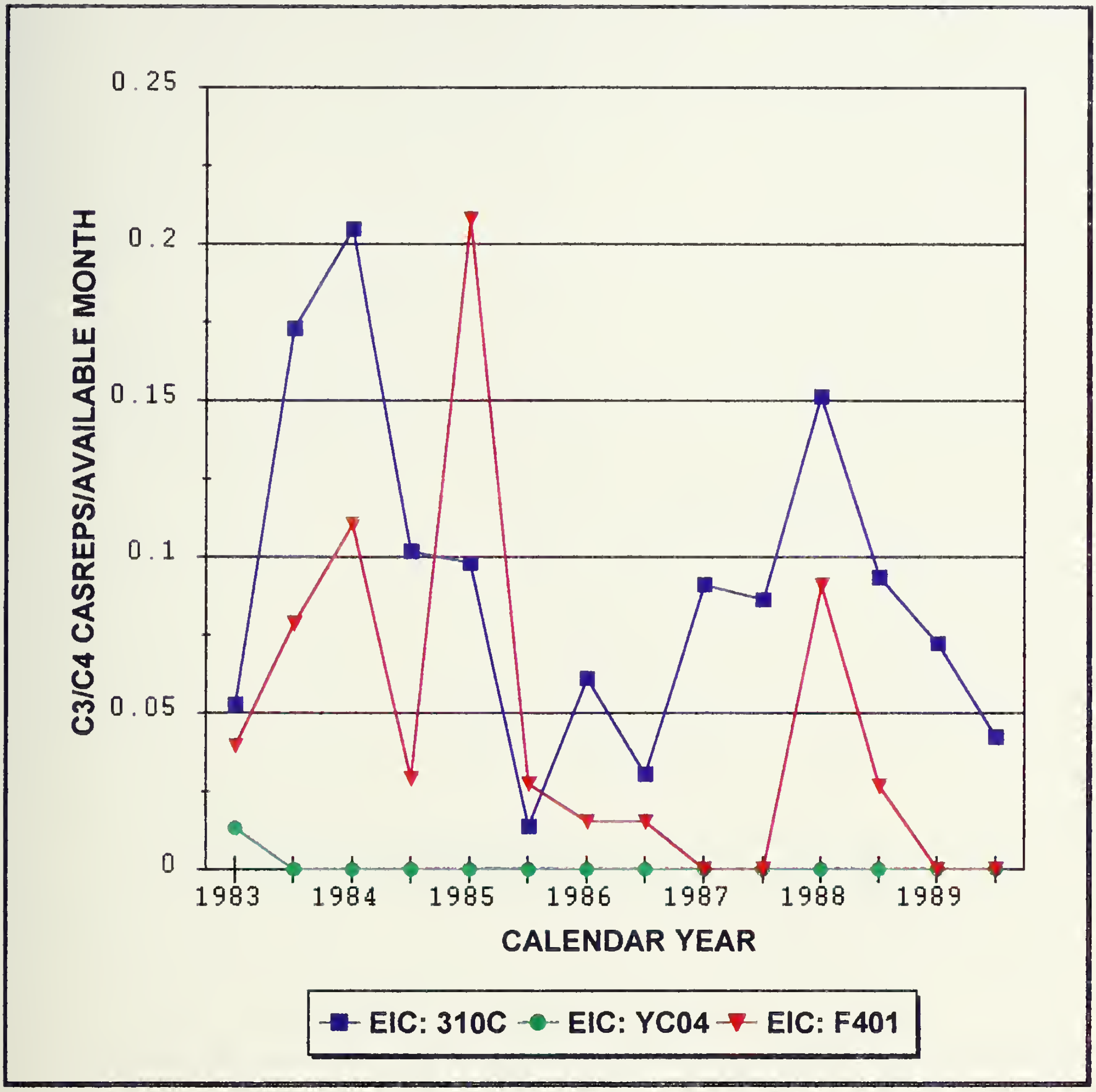

Figure 9. C3/C4 Casreps for selected EICs

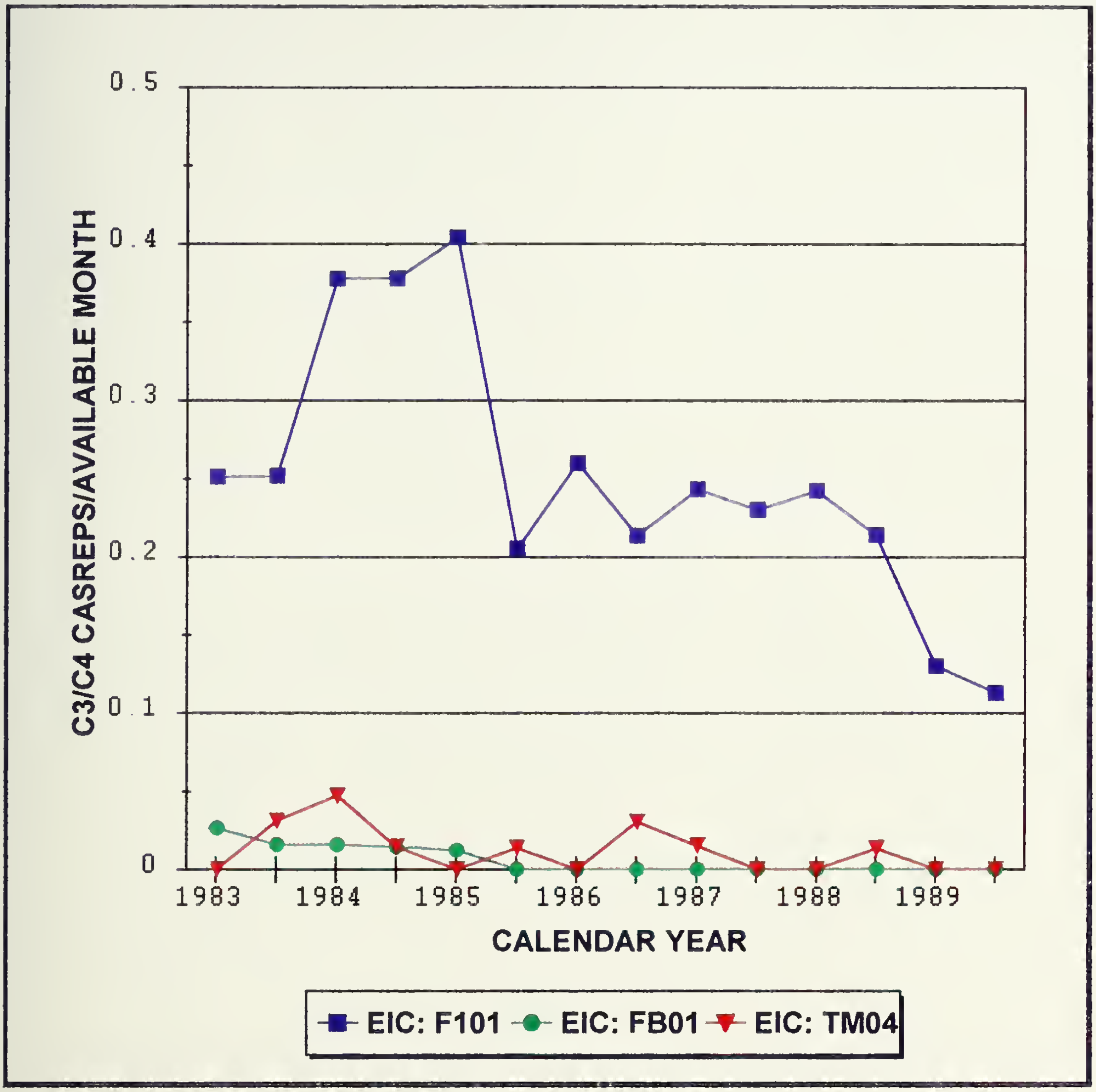

Figure 10. C3/C4 Casreps for Selected EICs

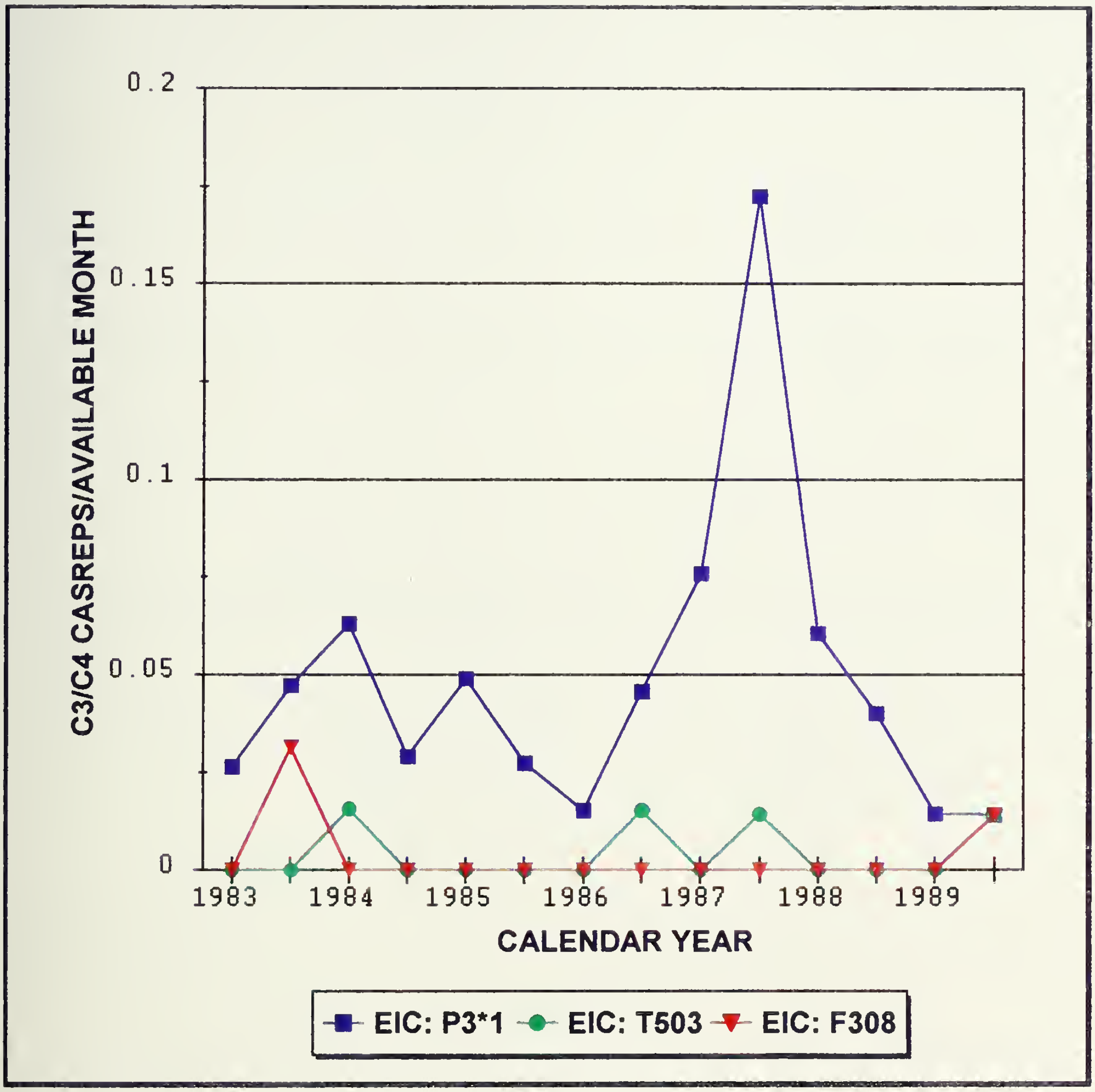

Figure 11. C3/C4 Casreps for Selected EICs

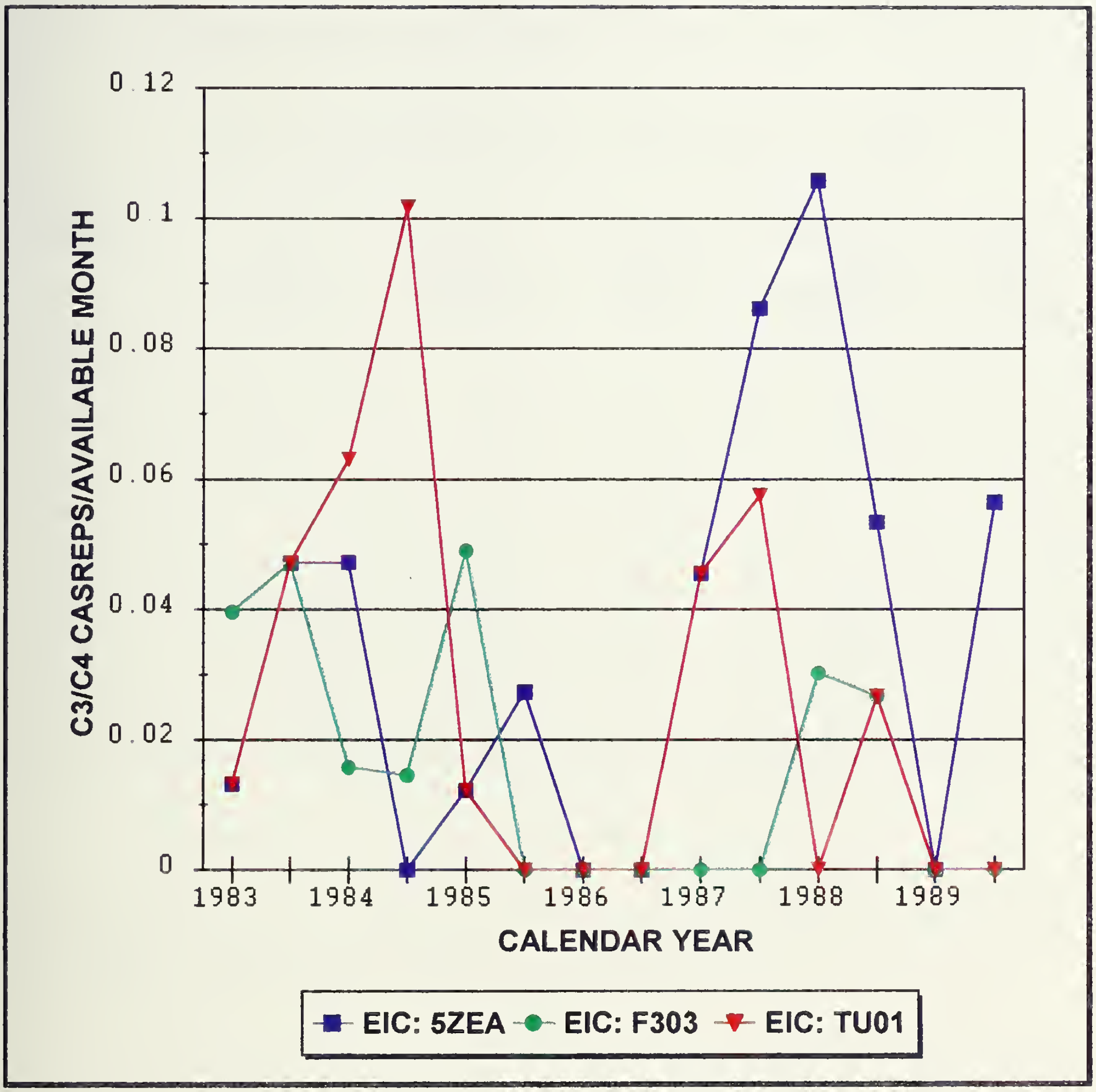

Figure 12. C3/C4 Casreps for Selected EICs

2. Operational Availability Data

Analysis of the operational availability data is fairly straightforward. The data, first presented in Table 4-2, is displayed again in Table 5-4.

TABLE 5-4. OPERATIONAL AVAILABILITY DATA

SHIP	PM STARTING DATE	DAYS IN ROH STRATEGY	DAYS IN ROH AVAIL	DAYS IN PM STRATEGY	DAYS IN PMAs & DPMAs
LPH 2	03/03/87	2,983	578	2,131	220
LPH 3	03/31/89	3,742	581	1,372	267
LPH 7	11/09/84	2,139	483	2,975	427
LPH 3	07/31/85	2,403	549	2,711	330
LPH 10	06/07/86	2,714	580	2,400	299
LPH 11	09/29/87	3,193	643	1,921	291
LPH 12	11/06/85	2,501	521	2,613	359
TOTAL DAYS IN PERIOD FOR ALL SHIPS = 5,114 DAYS					

Applying the above data to Equations (1) and (2), the percentage of time that each ship was available for operations under both strategies can be determined.

$$1 - \frac{\text{Days in ROH Availabilities}}{\text{Days Under ROH Strategy}} \qquad \textbf{(1)}$$

$$1 - \frac{\text{Days in PMAs \& DPMAs}}{\text{Days Under PM Strategy}} \qquad \textbf{(2)}$$

By multiplying the percentages by 365, the number of days per year each ship was available for operations can be determined. Table 5-5 displays the results of the calculations.

TABLE 5-5. MAINTENANCE STRATEGIES: TIME AVAILABLE

	ROH STRATEGY		PM STRATEGY	
SHIP	**% TIME AVAILABLE**	**DAYS/YR AVAILABLE**	**% TIME AVAILABLE**	**DAYS/YR AVAILABLE**
LPH 2	81.6	298	89.7	327
LPH 9	84.5	308	80.5	294
LPH 7	87.4	283	85.6	312
LPH 9	77.2	282	87.8	320
LPH 10	78.6	287	87.5	319
LPH 10	79.9	292	84.9	319
LPH 12	79.2	289	86.3	315

Averaging the data in Table 5-5 across all the ships in the class results in the data found in Table 5-6 below.

TABLE 5-6. OPERATIONAL AVAILABILITY: CLASS AVERAGE

	ROH STRATEGY		PM STRATEGY	
	% TIME AVAILABLE	**DAYS/YR AVAILABLE**	**% TIME AVAILABLE**	**DAYS/YR AVAILABLE**
AVG.	79.6	291	86.0	314

VI. CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

The objective of this thesis was to compare the depot level maintenance costs for the LPH 2 class before and after a change in maintenance strategy to determine if a cost savings has been realized. Additionally, analysis of two measures of readiness were to be made to determine if a change, for better or worse, had occurred in the readiness of the ships. With those objectives in mind, the research questions are restated and answered below.

B. RESEARCH QUESTIONS

As a result of the research, the research questions are answered as follows:

1. Did the change in maintenance strategy for the LPH 2 class from Regular Overhaul to Phased Maintenance result in a cost savings to the Navy?

To answer this question, two areas will be discussed. First, in the case of the two cost elements in which only observation of general trends was desired, Figures 2 through 5 indicate a downward trend in annual costs. With cost element 3.0 representing Total Depot Maintenance, the normalized data showed a clear downward trend with the exception of a spike in 1983. From the numbers, the apparent

cause of the spike was a modest level of expenditure spread over a meager 2.3 shipyard months. However, because the spike is so severe, the author is assuming that there is an error in some of the data. With cost element 3.2 representing Non Scheduled Ship Repair, a similar spike appeared in 1983 in the normalized plot. While this spike can not be "explained away", the trend of this cost element was sharply downward.

The second area to be discussed is the actual cost of the maintenance availabilities, cost element 3.1.1 for the Regular Overhaul strategy and cost element 3.1.2 for the Phased Maintenance strategy. The results, as evident in Table 5-1 and Figure 4, are more profound. With an average daily cost of $16,641 under the ROH strategy and $6,234 under the PM strategy, it is clear that the Phased Maintenance strategy has resulted in a cost savings to the Navy.

There are other factors that contributed to the difference in costs such as shrinking resources and improvements in preventive maintenance, to name a couple. However, the majority of the cost savings is appropriately attributed to the new maintenance strategy.

2. Did the change in maintenance strategy result in an improvement in ship readiness as measured by trends in C3 and C4 Casualty Reports?

As previously stated, the casrep analysis was the least scientific of the group. The casreps taken as a whole

displayed two unexplainable spikes, one before the change in maintenance strategy(1981) and one well after the change(1989), which would seem to indicate that the number of casreps is independent of the maintenance strategy. However, when casrep trends of the selected EICs were observed, the results were different. Trends for most of the EICs either improved or stayed about the same, while trends for two seemed to mirror the trends of total casreps and the trend for one EIC got worse. While the degree of improvement resulting from the change in maintenance strategy could be argued, there is no argument to the contrary. The stronger point to be made here is that with the move from the traditional "time directed repairs" to the newer and far less expensive concept of "condition directed repairs", there was no apparent increase in the number of equipment failures.

3. Did the change in maintenance strategy result in an improvement in ship readiness as measured by average days per year the ship was available for operations?

Over the time span of this thesis it is clear that under the Phased Maintenance strategy the operational availability of the ships in the class improved. The percentage of time the ships were available for operations increased from 79.6% to 86.0% on average. In terms of average number of days per year the ships were available for operations the figures were 291 days/year for the Regular

Overhaul strategy and 314 days/year for the Phased Maintenance strategy, again demonstrating the improvement.

C. AREAS FOR FURTHER RESEARCH

The first area for further research that comes to mind is a continuation of cost comparisons of various maintenance strategies. Many of the ship classes currently in service in the Navy have changed from one maintenance strategy to another over the years. Research similar to that conducted in this thesis could be applied to other ship classes.

Along the same lines, research that attempts to capture all of the cost differentials for the different maintenance strategies would be useful. For example, as mentioned earlier, the difference in training cost incurred due to the different maintenance strategies is likely to be significant. That is to say, for a ship to go into the shipyard for 100 days vice 300 days, crew turnover would be less and therefore the number of new individuals requiring training would decrease. If reliable data could be found, training cost and other cost could be included in the analysis. Possibly the greatest cost differential to be studied would be the difference in the number of ships needed in a given class under different maintenance strategies. In other words, if the average operational availability for a class of 30 ships could be improved by 6%, would the Navy need 30 or would 27 be sufficient?

Another area for further research would be to analysis ship classes that currently utilize the Engineered Operating Cycle strategy (such as the CG 47 class) to determine the feasibility of converting the class to the Phased Maintenance strategy to increase operational availability (this would be rather technical and would probably require more than one thesis to analyze a class).

APPENDIX A. LIST OF ACRONYMS AND ABBREVIATIONS

CASREP	Casualty Report
CO	Commanding Officer
COH	Complex Overhaul Availability
DMP	Depot Modernization Period
DPIA	Docking Phased Incremental Availability
DPMA	Docking Phased Maintenance Availability
DPMF	DPMA (Fixed Price Contract)
DSRA	Docking Selected Restricted Availability
EIC	Equipment Identification Code
EOC	Engineered Operating Cycle (Strategy)
EOH	Engineered Overhaul Availability
GAO	Government Accounting Office
IMA	Intermediate Maintenance Activity
IMAV	Intermediate Maintenance Availability
IMP	Incremental Maintenance Plan (Strategy)
LPH	Designation for Amphibious Assault Ship
NAVCOMPT	Office of the Comptroller of the Navy
NAVSEA	Naval Sea Systems Command
NRF	Naval Repair Facility
NSY	Naval Shipyard
OPNAV	Office of the Chief of Naval Operations
OVHL	Overhaul

PIA	Phased Incremental Availability
PM	Phased Maintenance (Strategy)
PMA	Phased Maintenance Availability
PMF	PMA (Fixed Price Contract)
PROG	Progressive Maintenance (Strategy)
RAV	Restricted Availability
RCOH	(Nuclear) Refueling COH Availability
RFOH	(Nuclear) Refueling Overhaul Availability
ROH	Regular Overhaul Availability (Strategy)
SIMA	Shore Intermediate Maintenance Activity
SRA	Selected Restricted Availability
TYCOM	Type Commander

APPENDIX B. VAMOSC(SHIPS) COST DATA

The following tables display the cost data retrieved from the Visibility and Management of Operating and Support Costs (VAMOSC) Management Information System. The cost values are expressed in 1992 dollars as inflated using NAVCOMPT inflation indices. [Refs. 10, 11, and 12]

TABLE B-1. VAMOSC COST ELEMENT DESCRIPTIONS

ELEMENT	DESCRIPTION
3.0	Direct Depot Maintenance
3.1	Scheduled Ship Overhaul
3.1.1	Regular Overhaul (ROH)
3.1.2	SRA, DSRA, PMA, or DPMA
3.2	Non-Scheduled Ship Repair

TABLE B-2. LPH 2 COST DATA

	VAMOSC-SHIPS COST ELEMENTS				
YEAR	3.0	3.1	3.1.1	3.1.2	3.2
1979	$ 3,247,762	$ 0	$ 0	$ 0	$ 2,179,599
1980	$ 2,836,512	$ 206,839	$ 206,839	$ 0	$ 2,292,951
198[illegible]	$ 18,748,384	$ 2,936,376	$ 2,936,376	$ 0	$ 2,527,885
198[illegible]	$ 68,907,929	$ 41,944,288	$ 41,944,288	$ 0	$ 17,145
198[illegible]	$ 19,904,528	$ 995,030	$ 995,030	$ 0	$ [illegible],802,848
198[illegible]	$ 4,526,164	$ 0	$ 0	$ 0	$ 2,646,858
198[illegible]	$ 14,846,593	$ 0	$ 0	$ 0	$ 4,105,022
198[illegible]	$ 23,689,679	$ 19,631	$ 19,631	$ 0	$ 4,292,890
198[illegible]	$ 21,996,630	$ 13,130,386	$ 13,130,386	$ 0	$ 439,436
1988	$ 1,848,233	$ 558,583	$ 493,568	$ 65,015	$ 293,366
1989	$ 7,130,970	$ 4,470,759	$ 0	$ 4,470,759	$ 400,391
1990	$ 836,791	$ 154,746	$ 0	$ 154,746	$ 370,910
199[illegible]	$ 1,967,428	$ 1,127,660	$ 0	$ 1,127,660	$ 287,829
1992	$ 5,905,228	$ 5,352,593	$ 0	$ 5,352,593	$ 319,657

TABLE B-3. LPH 3 COST DATA

	VAMOSC-SHIPS COST ELEMENTS				
YEAR	3.0	3.1	3.1.1	3.1.2	3.2
1979	$ 93,279	$ 26,466	$ 26,466	$ 0	$ 66,821
1980	$ 2,462,908	$ 58,804	$ 58,804	$ 0	$ 2,393,710
1981	$ 9,724,621	$ 4,509,232	$ 4,509,232	$ 0	$ 5,190,029
1982	$ 36,422,672	$ 34,340,203	$ 34,340,203	$ 0	$ 1,411,086
1983	$ 5,811,327	$ 628,259	$ 628,259	$ 0	$ 164,571
1984	$ 11,680,511	$ 0	$ 0	$ 0	$ 669,829
1985	$ 3,857,860	$ 0	$ 0	$ 0	$ 2,777,608
1986	$ 4,970,035	$ 298,133	$ 298,133	$ 0	$ 2,646,194
1987	$ 2,856,587	$ 770,611	$ 770,611	$ 0	$ 995,187
1988	$ 20,559,786	$ 16,201,561	$ 16,201,561	$ 0	$ 571,480
1989	$ 69,144,696	$ 61,234,138	$ 61,234,138	$ 0	$ 2,173,467
1990	$ 1,537,246	$ 23,408	$ 0	$ 23,408	$ 1,286,141
1991	$ 5,944,154	$ 4,337,519	$ 0	$ 4,337,519	$ 1,100,955
1992	$ 2,305,926	$ 2,044,494	$ 0	$ 2,044,494	$ 124,044

TABLE B-4. LPH 7 COST DATA

	VAMOSC-SHIPS COST ELEMENTS				
YEAR	3.0	3.1	3.1.1	3.1.2	3.2
1979	$ 53,797,983	$ 43,160,086	$ 43,160,086	$ 0	$ 210,529
1980	$ 10,236,373	$ 5,975,154	$ 5,975,154	$ 0	$ 154,835
1981	$ 1,491,995	$ 16,196	$ 16,196	$ 0	$,468,603
1982	$ 2,801,676	$ 9,004	$ 0	$ 9,004	$ 2,600,821
1983	$ 1,946,743	$ 382	$ 382	$ 0	$,598,351
1984	$ 43,483,178	$ 25,122,262	$ 25,122,262	$ 0	$ 2,077,468
1985	$ 14,062,763	$ 8,540,881	$ 8,540,881	$ 0	$,181,463
1986	$ 8,409,734	$ 660,927	$ 47,420	$ 613,507	$ 124,701
1987	$ 2,905,435	$ 687,573	$ 0	$ 687,573	$ 444,646
1988	$ 812,669	$ 27,760	$ 0	$ 27,760	$ 417,864
1989	$ 1,393,241	$ 141,154	$ 0	$ 141,154	$ 400,349
1990	$ 14,337,495	$ 12,277,622	$ 0	$ 12,277,622	$ 182,783
1991	$ 2,725,679	$ 1,761,370	$ 0	$ 1,761,370	$ 115,844
1992	$ 1,165,570	$ 542,260	$ 0	$ 542,260	$ 62,419

TABLE B-5. LPH 9 COST DATA

	VAMOSC-SHIPS COST ELEMENTS				
YEAR	**3.0**	**3.1**	**3.1.1**	**3.1.2**	**3.2**
1979	$ 1,126,484	$ 63,248	$ 63,248	$ 0	$ 544,512
1980	$ 47,913,999	$ 35,373,462	$ 35,373,462	$ 0	$ 221,816
1981	$ 5,271,323	$ 2,520,907	$ 2,520,907	$ 0	$ 2,010,191
1982	$ 1,673,890	$ 0	$ 0	$ 0	$ [illegible],449,958
1983	$ 3,232,640	$ 0	$ 0	$ 0	$ 3,164,118
1984	$ 7,617,031	$ 1,291,248	$ 1,291,248	$ 0	$ 3,705,087
1985	$ 51,691,869	$ 33,594,198	$ 33,594,198	$ 0	$ [illegible],004,837
1986	$ 6,186,904	$ 1,785,312	$ 1,785,312	$ 0	$ 2,157,452
1987	$ 13,190,089	$ 7,127,315	$ 0	$ 7,127,315	$ 982,349
1988	$ 4,913,517	$ 1,970,829	$ 0	$ 1,970,829	$ 444,055
1989	$ 14,209,514	$ 7,072,043	$ 0	$ 7,072,043	$ 190,762
1990	$ 3,312,918	$ 1,650,816	$ 0	$ 1,650,816	$ 273,981
1991	$ 1,015,153	$ 339,938	$ 0	$ 339,938	$ 185,794
1992	$ 5,369,555	$ 5,027,211	$ 0	$ 5,027,211	$ 142,062

TABLE B-6. LPH 10 COST DATA

	VAMOSC-SHIPS COST ELEMENTS				
YEAR	**3.0**	**3.1**	**3.1.1**	**3.1.2**	**3.2**
1979	$ 1,562,071	$ 0	$ 0	$ 0	$,561,801
1980	$ 8,658,919	$ 7,641,192	$ 7,641,192	$ 0	$,014,821
1981	$ 1,581,776	$ 533,222	$ 533,222	$ 0	$,042,812
1982	$ 2,982,011	$ 493,523	$ 493,523	$ 0	$ 2,425,590
1983	$ 2,388,526	$ 0	$ 0	$ 0	$ 2,248,180
1984	$ 9,121,068	$ 33,878	$ 33,878	$ 0	$ 8,298,220
1985	$ 54,585,890	$ 14,641,062	$ 14,641,062	$ 0	$ 697,292
1986	$ 5,010,758	$ 0	$ 0	$ 0	$ 2,390,080
1987	$ 1,507,665	$ 202,985	$ 202,985	$ 0	$ 694,201
1988	$ 5,754,654	$ 3,804,563	$ 169,400	$ 3,635,163	$ 517,840
1989	$ 538,723	$ 170,679	$ 162,316	$ 8,362	$ 101,116
1990	$ 26,525,308	$ 7,332,543	$ 1,256	$ 7,331,287	$ 211,943
1991	$ 3,186,473	$ 300,700	$ 2,793	$ 297,908	$ 505,059
1992	$ 8,943,517	$ 7,194,720	$ 0	$ 7,194,720	$ 404,166

TABLE B-7. LPH 11 COST DATA

	VAMOSC-SHIPS COST ELEMENTS				
YEAR	**3.0**	**3.1**	**3.1.1**	**3.1.2**	**3.2**
1979	$ 1,396,218	$ 0	$ 0	$ 0	$ 1,293,494
1980	$ 3,065,420	$ 1,962,466	$ 1,962,466	$ 0	$ 1,022,316
1981	$ 52,941,547	$ 33,087,919	$ 33,087,919	$ 0	$ 2,585,241
1982	$ 10,682,835	$ 7,855,857	$ 7,855,857	$ 0	$ 332,852
1983	$ 10,635,755	$ 0	$ 0	$ 0	$ 6,065,223
1984	$ 3,288,852	$ 0	$ 0	$ 0	$ 2,810,708
1985	$ 4,906,325	$ 0	$ 0	$ 0	$ 1,680,029
1986	$ 8,477,732	$ 4,379,655	$ 4,379,655	$ 0	$ 2,911,767
1987	$ 24,671,178	$ 10,523,556	$ 10,523,556	$ 0	$ 599,376
1988	$ 4,222,869	$ 1,848,845	$ 1,701,960	$ 146,885	$ 1,059,569
1989	$ 921,981	$ 17,516	$ 0	$ 17,516	$ 813,074
1990	$ 15,518,248	$ 3,315,429	$ 0	$ 3,315,429	$ 221,576
1991	$ 3,265,600	$ 873,145	$ 0	$ 873,145	$ 232,887
1992	$ 14,786,561	$ 13,221,386	$ 0	$ 13,221,386	$ 343,933

TABLE B-8. LPH 12 COST DATA

	VAMOSC-SHIPS COST ELEMENTS				
YEAR	**3.0**	**3.1**	**3.1.1**	**3.1.2**	**3.2**
1979	$ 1,727,452	$ 382,028	$ 382,028	$ 0	$ 1,260,065
1980	$ 8,388,323	$ 5,452,077	$ 5,452,077	$ 0	$ 443,199
1981	$ 45,264,663	$ 36,703,705	$ 36,703,705	$ 0	$ 66,084
1982	$ 9,980,781	$ 3,147,801	$ 3,147,801	$ 0	$ 5,814,811
1983	$ 5,962,201	$ 2,296	$ 2,296	$ 0	$ 854,044
1984	$ 19,299,057	$ 0	$ 0	$ 0	$ 7,075,308
1985	$ 51,648,063	$ 19,484,429	$ 19,484,429	$ 0	$ 1,014,550
1986	$ 17,589,191	$ 9,278,171	$ 9,278,171	$ 0	$ 1,236,628
1987	$ 2,209,470	$ 690,573	$ 31,535	$ 659,038	$ 937,083
1988	$ 4,963,558	$ 2,714,860	$ 110,761	$ 2,604,099	$ 140,615
1989	$ 1,505,712	$ 373,064	$ 139,955	$ 233,109	$ 303,863
1990	$ 5,256,548	$ 4,151,832	$ 37,878	$ 4,113,954	$ 378,516
1991	$ 7,321,692	$ 6,118,162	$ 763	$ 6,117,399	$ 293,917
1992	$ 1,512,610	$ 795,490	$ 0	$ 795,490	$ 0

APPENDIX C. C3/C4 CASUALTY REPORT DATA

The following tables display the C3 and C4 casualty report data provided by NAVSEA. Table C-1 provides a description of the twelve selected equipment identification codes. Table C-2 displays the total number of C3/C4 casualty reports for all equipment identification codes and Tables A-3 through C-5 provide C3/C4 casrep numbers for the selected EICs.

TABLE C-1. SELECTED EQUIPMENT IDENTIFICATION CODES

EIC	DESCRIPTION
310C	60HZ Steam Turbine Driven Generator Set
F101	D-Express Header Type Boiler (Main Steam)
YC04	Boat Davits
FB01	Motor Driven Main Circulating Pump
P3*1	AN/SPS 40 Radar Set
5ZEA	MK 115 MOD 0 Guided Missile Fire Control Sys.
T503	Direct Expansion (R-12) Refrigeration Plant
F303	Turbine Driven Main Feed Pump (Centrifugal)
F401	Blower Group (Combustion, Main Propulsion)
TM04	Anchor Windlass
F308	Turbine Driven Main Feed Booster Pump
TU01	Deck Edge Elevators

TABLE C-2. TOTAL C3/C4 CASREPS FOR THE LPH 2 CLASS

YEAR	CASREPS	YEAR	CASREPS	YEAR	CASREPS
1979	77	1989	55	1989	140
1980	100	1989	43	1989	96
1981	170	1986	58	1991	64
1982	135	1987	82	1992	60
1983	141	1988	102		

TABLE C-3. C3/C4 CASREP DATA FOR SELECTED EICs

	EQUIPMENT IDENTIFICATION CODES			
YEAR	310C	F101	YC04	FB01
1979	4	19	1	2
1984	11	16	0	1
1981	13	24	0	1
1988	7	26	0	1
1983	6	33	9	1
1984	1	10	4	0
1985	4	17	4	0
1986	2	10	9	0
1984	4	16	4	0
1988	6	16	9	0
1984	10	16	4	0
1984	7	16	9	0
1984	5	9	9	0
1992	3	8	0	0

TABLE C-4. C3/C4 CASREP DATA FOR SELECTED EICs

	EQUIPMENT IDENTIFICATION CODES			
YEAR	P3*1	5ZEA	T503	F303
1979	2	1	0	3
1980	3	3	0	3
1981	4	3	1	1
1982	2	0	0	1
1983	4	1	0	0
1989	2	2	0	0
1985	[illegible]	0	7	0
1989	3	0	1	0
1987	5	3	0	0
1989	12	6	1	0
1989	4	7	0	2
1990	3	4	0	2
1991	1	0	0	0
1992	1	4	1	0

TABLE C-5. C3/C4 CASREP DATA FOR SELECTED EICs

	EQUIPMENT IDENTIFICATION CODES			
YEAR	F401	TM04	F308	TU01
1979	3	0	0	1
1990	5	2	2	[illegible]
1981	7	3	3	0
1982	2	1	0	7
1983	17	0	0	1
1981	2	1	0	0
1989	1	0	0	0
1986	1	2	3	0
1987	0	1	0	3
1998	0	0	0	0
1989	0	0	0	0
1990	2	1	0	2
1981	0	3	3	0
1992	0	0	1	0

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